IN SITU CHEMICAL ANALYSIS OF SMALL BODIES WITH LASER MASS SPECTROMETRY

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ABSTRACT

Focused missions to small solar system bodies such as asteroids, comets, and planetary satellites represent a uniquely powerful approach to probing the earliest processes in our solar system including the accretion and distribution of primordial materials that may have seeded the origin of life on Earth. These include surface missions that perform a detailed *in situ* chemical analysis of the regolith in its pristine state. The analysis could be effectively applied alone or in conjunction with a sample return campaign. With myriad instrumentation options for chemical analysis now developed, suitability for implementation may be driven primarily by the particular capabilities and the operational flexibility of a technique within specific mission objectives and constraints. We have found that pulsed laser mass spectrometry offers a very strong combination of capabilities and flexibility for surface analysis of airless small bodies.

The basic capabilities of a laser ablation mass spectrometer (LA-MS) on an asteroid or planetary encounter have been described [1,2]. Originally the technique was to be applied from a hovering spacecraft at Phobos, with the laser exciting ions directly from the regolith, and mass analyzing them after they drifted across the 30-80 m gap. A more powerful investigation, and a far more compact instrument, is realized at closer working distances from a landed platform, where the laser may be used to sample sub-mm points on the surface selected from within the field of view of a high-magnification imager. Broad elemental composition with limits of detection as low as a few parts per million by weight may be realized within the resource limits of such a mission. Repeated laser pulses could additionally provide depth profiles over mm-cm scales to characterize subtle signatures of space weathering, shielded ice, and impact-induced depletions that could be lost during sample acquisition/return activities. In an alternate configuration, “ground truth” LA-MS analysis of materials being collected for return to Earth may be accomplished using a defined sampling system, such as in the laser mass analyzer (LASMA) instrument on the Phobos Grunt mission.

It is possible to push the mass of a miniature LA-MS to within the ~1 kg range, and there may be situations where minimal instrument mass is the primary requirement. In the mass range of several kg, however, a qualitative increase in analytical performance and flexibility can be envisioned that may prove critical for some missions. For example, the optimal measurement conditions for reproducible element ratio data or for detection of trace species such as rare earth elements may require tuning of parameters such as laser intensity, focal diameter, ion lens and detector voltages, and acquisition range. At the same time, the instrument may need to account for a variable working distance if deployed from a robotic arm and/or over a rough surface. Possible developments to optimize the performance and flexibility of LA-MS will be discussed.

1. Brinckerhoff, W. B. (2005) *Planet. Space Sci. 53*, 817-838.
2. Rohner, U. *et al.* (2004) *Rev. Sci. Instrum. 75*, 1314-1322.